UNITED STATES NAVY - CANADIAN FORCES
SOLID STATE FLIGHT DATA RECORDER/CRASH POSITION LOCATOR
EXPERIMENT ON THE B-720 CONTROLLED IMPACT DEMONSTRATION

D. M. WATTERS
Naval Air Test Center
Patuxent River, Maryland 20670-5304

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INTRODUCTION

The Solid State Flight Data Recorder/Crash Position Locator (SSFDR/CPL) project was established in January 1983 as a joint United States Navy/Canadian Forces (USN/CF) project under the auspices of the international Air Standardization Coordinating Committee (ASCC) Working Party 19 Airborne Electronic Equipment and Test Project Agreement (TPA 805-19). The prototype SSFDR and CPL Radio Beacon Airfoil (RBA-46) was developed by Leigh Instruments, Ltd., Carleton Place, Ontario, Canada configured for Boeing B-707 or B-720 type aircraft. Standard United States Air Force E-3A (B-707) AN/URT-26(V)19 Radio Beacon Set Base (MRU-27), Battery Assembly (ARU-21) and ejection frangible switches were installed in the National Aeronautics and Space Administration (NASA)/Federal Aviation Administration (FAA) B-720 aircraft by the Naval Air Test Center (NAVAIRTESTCEN), Patuxent River, Maryland, and the Naval Air Rework Facility, North Island, San Diego, California. Later the prototype RBA-46 and Dispenser (ARU-21) were installed and ground tested in the B-720 aircraft. This SSFDR/CPL system (figures 1 and 2) was aboard the NASA/FAA B-720 aircraft (figure 3) during the Controlled Impact Demonstration (CID) conducted on 1 December 1984 at NASA Dryden Flight Research Facility, Edwards Air Force Base, California.

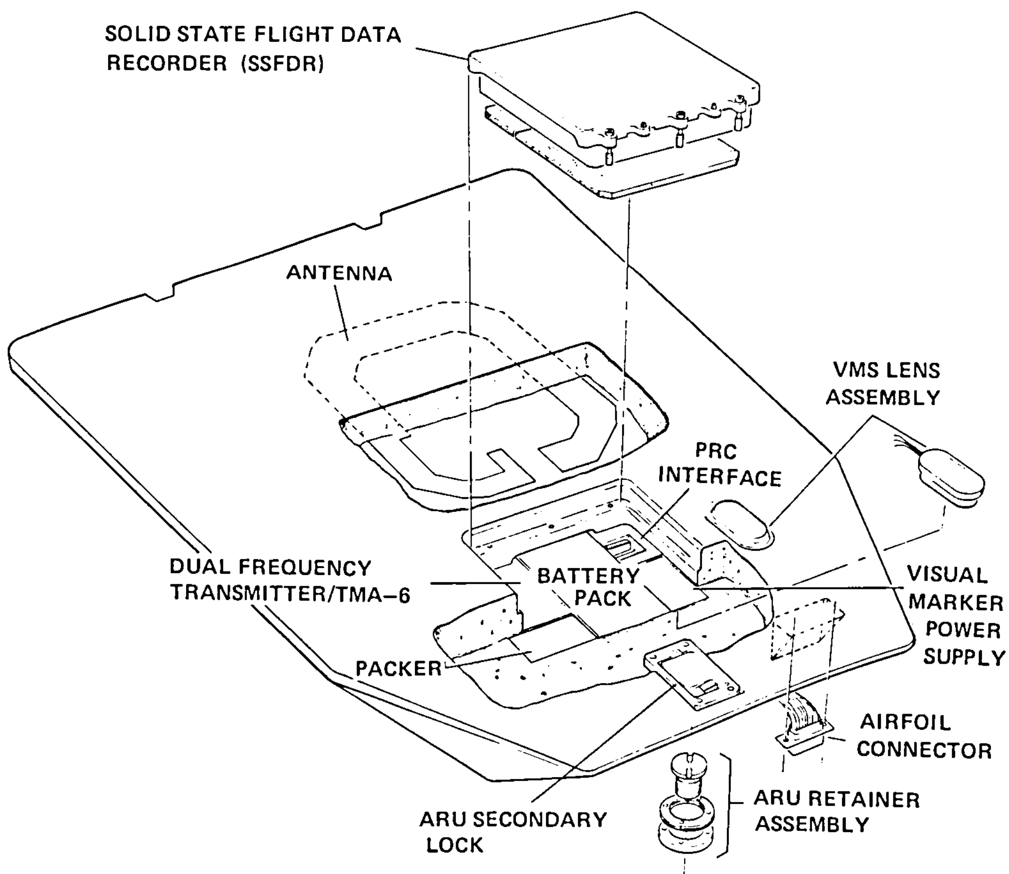

Figure 1
B-720 AIRFOIL (RBA-46) PAYLOAD CONFIGURATION

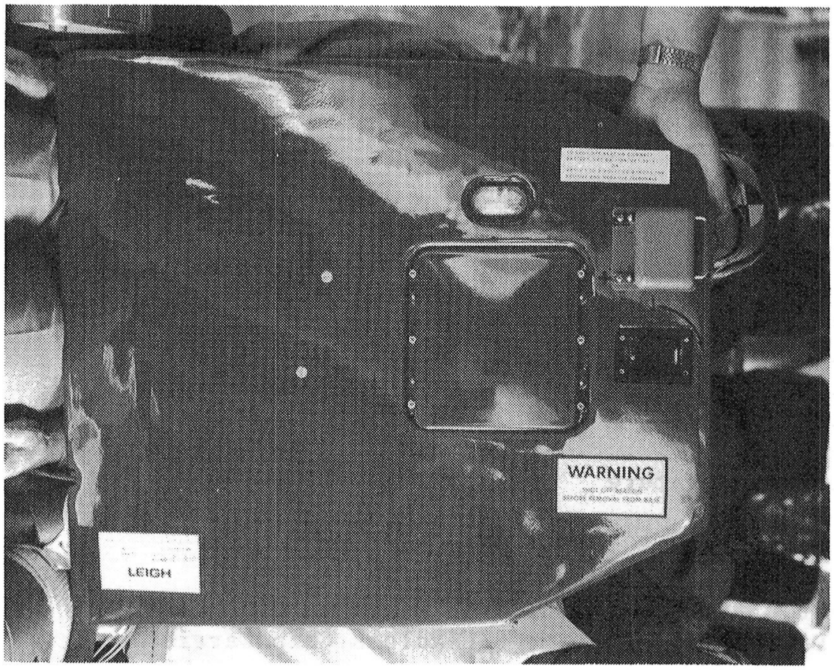

Figure 2
B-720 AIRFOIL (RBA-46) PRE-CID HARDWARE

Figure 3
B-720 AIRCRAFT/RBA-46 AIRFOIL INSTALLATION

SOLID STATE FLIGHT DATA RECORDER DEVELOPMENT

The Solid State Flight Data Recorder (SSFDR) shown in figure 4 was designed using Electronically Erasable Programmable Read Only Memory (EEPROM) Silicon Nitride Oxide Semiconductor (SNOS) chip technology as specified below:

DEVICE SPECIFICATION

Type	- EEPROM, NCR 52832, SNOS
Capacity	- 32 Kbits (4k x 8)*
Write Rate	- 12.8 Kbits/sec
Read Rate	- 500 Kbits/sec
Erase Rate	- 300 Kbits/sec
Endurance	- 10^5 Cycles/Memory Cell
Retention	- 30 Days at Stated Endurance
Operating Voltage	- 5 VDC ±10%
Packaging	- Encapsulated Surface Mount Technology
Operating Temperature	- (-55^oC to $+125^oC$)

INTERNAL MODULE SPECIFICATION

Form Factor	- 2.6" x 1.8" x 0.3" (1.4 in^3)
No. of Devices	- 8 Leadless Chip Carrier
Packaging	- Encapsulated Polyurethane Foam

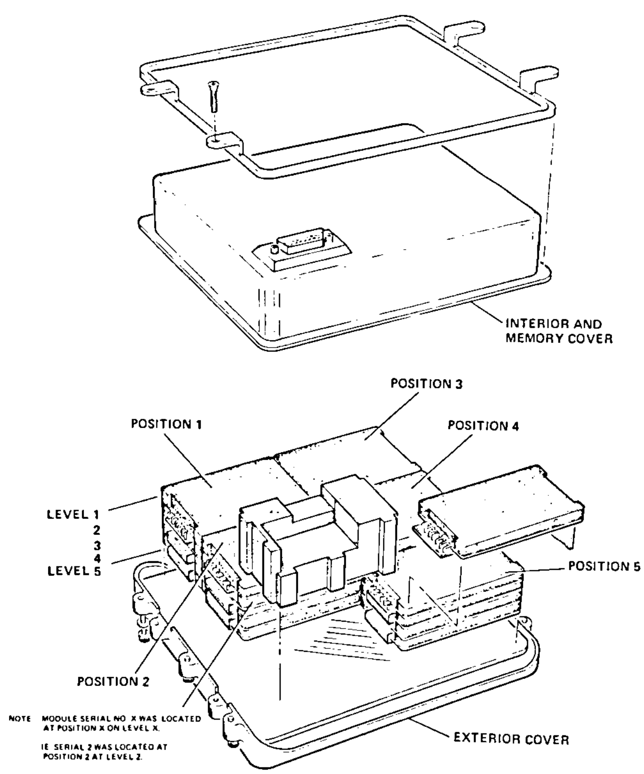

Figure 4
SSFDR MEMORY MODULE ARRANGEMENT

SSFDR SPECIFICATIONS

Form Factor	- 7.12" x 7.0" x 1.55" (77.25 in^3)
Weight	- 3 lbs
Power	- 1.1 Watts (max)
No. of Modules	- 25 (max)
No. of Modules (B-720)	- 5 with devices & 20 dummy
Memory Capacity	
	- 6 Mbits* (32 Kbit chips)
Packaging	- Aluminum, Fiberglass, Intumescent coating

* Only 32 Kbit EEPROM devices were available for this development. Currently, 64 Kbit devices are available that would effectively increase the maximum SSFDR capacity to 12 Mbit.

The B-720 SSFDR contained five memory modules and twenty dummy modules. Each of the five memory modules contained two 32 Kbit memory chips (64 Kbits total). The five memory modules were spaced to measure thermal gradients within the SSFDR. The memory modules/chips (320 Kbits total) were pre-programmed with alternating ones and zeros (checkerboard pattern) prior to CPL/B-720 installation. Also, temperature stick-on indicators were attached to each memory module and interior and exterior SSFDR covers prior to CPL/B-720 installation.

CRASH POSITION LOCATOR DEVELOPMENT

The design concept for the RBA-46 CPL was formulated by Mr. D. M. Watters, NAVAIRTESTCEN, in early 1983. The design concept included the following new features currently not included in production CPLs:

1. Overt radio beacon transmission at 121.5 MHz (civilian), 243 MHz (military) and 406 MHz (SARSAT) emergency frequencies.

2. Covert radio beacon transmission (spread frequency 2.55 MHz to 300 MHz transceiver-transponder).

3. Remote transceiver frequency selection switch.

4. Remote overt/covert frequency selection switch.

5. Automatic antenna tuning.

6. Visual Marker Strobe (VMS).

7. Pyrotechnic operated CPL release unit.

Given these technical development requirements and contractual funding and schedule constraints, a detailed feasibility study was conducted and reported (reference (1)). It was concluded in this study that the following, although technically feasible, could not be implemented in the B-720 RBA-46 CPL:

1. 406 MHz SARSAT transmitter (hardware unavailable).

2. Covert radio beacon transceiver/transponder (AN/PRC-112(V) not available).

3. Remote frequency selection switches.

4. Automatic antenna tuning.

Thus the B-720 RBA-46 CPL design configuration was established as shown in figure 5 with electronic circuitry and space provisions to implement the figure 6 design configuration after the B-270 CID. The B-720 RBA-46 CPL overall specifications are as follows:

Form Factor	- 23" x 26" x 4.5" (1200 in^3)
Weight (with SSFDR)	- 11 lbs
Power Supply	- $LiSO_2$ Battery Pack
Power Draw	- 6.6A
Visual Marker Strobe	- Modified ACR/SDU-5
Overt Operating Frequencies	- 121.5 MHz and 243 MHz
Covert Operating Frequencies (AN/PRC-112(V) provisions)	- 255 to 300 MHz
Antenna	- "G" Shaped Broadband
Release Unit	- Pyrotechnic Squib Actuated

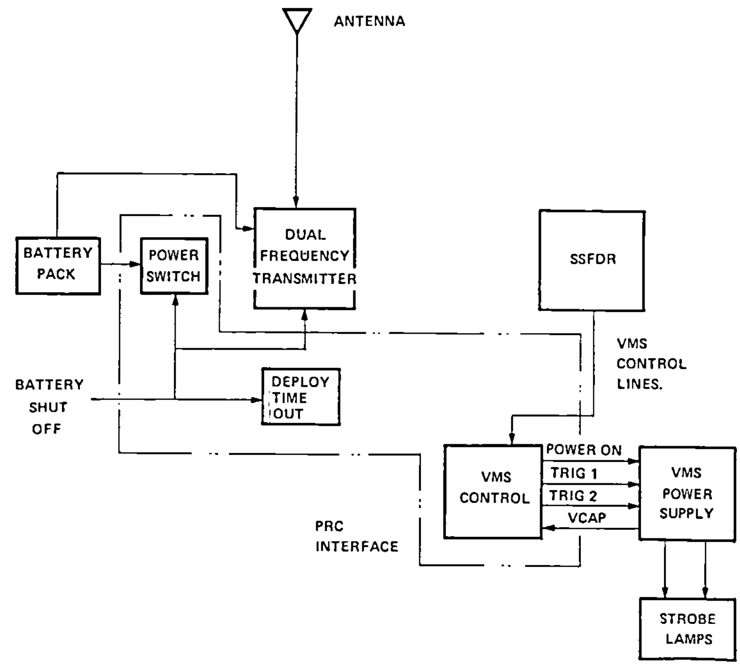

Figure 5
B-720/RBA-46 PAYLOAD BLOCK DIAGRAM

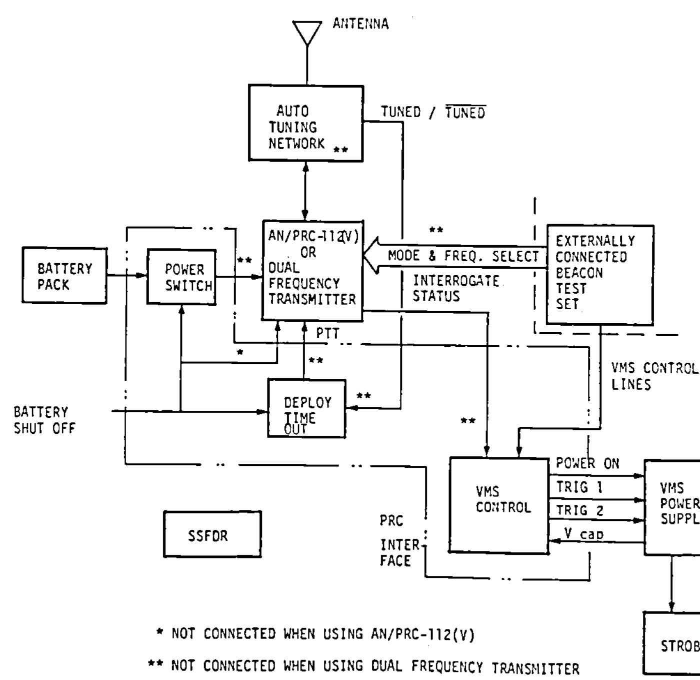

Figure 6
RBA-46 LOCATION RELATIVE TO B-720 AFTER CID

B-720 SSFDR/CPL CID

The NASA/FAA B-720 impacted onto the dry lake bed at Edwards AFB at 9:22 am, December 1, 1984. The engines on the left wing struck the ground first and yawed the aircraft to the left. The aircraft continued into the crash site grid striking the rhinos and strikers, which ripped open the right inboard engine and wing tanks. A fire ball then erupted from the right inboard engine engulfing the aircraft and the RBA-46 SSFDR/CPL. At the time of initiation of the fire, the RBA-46 airfoil had not ejected. The aircraft continued down the crash site grid, sliding and yawing to the left. The right wing separated from the fuselage, violently tumbling and spilling fuel, eventually coming to rest on the left side of the aircraft. The aircraft continued to slide finally coming to rest on the left edge of the gravel crash site grid. The CPL RBA-46 did not separate from the aircraft until the aircraft came to rest. It is clearly visible from video and camera coverage that when the airfoil did release, the aircraft was at a yaw angle of about 30° to 45°.

The radio beacon transmission was actuated and was picked up by the Navy P-3A chase aircraft for a short time, after which reception was lost. The pilot reported that he received a signal on both 121.5 MHz and 243 MHz for a period of approximately 5 seconds. Five minutes after the crash a portable direction finding unit located on the roof of the NASA Dryden Flight Research Facility, 4 miles distant from the crash, was unable to pick up the beacon transmission.

The fire crews started fighting the fires approximately 90 seconds after the time of impact. The crews continued to spray the fire with foam for over an hour and a half. The foam used by the fire crews is a 3% to 6% solution of AFFF (FC-203 Light Water Brand Aqueous Film Forming Foam) in water.

Approximately four hours after the crash the NASA/FAA safing team located the CPL and installed the Battery Shut-off (BSO) on the RBA-46.

Navy personnel access to the crash site was allowed on the morning of December 2, 1984. The CPL RBA-46 was found resting top side up, 15 feet forward and 13 feet perpendicular from the tray location on the starboard side of the aircraft. Figure 7 shows the final location of the CPL RBA-46. An immediate inspection indicated the airfoil suffered moderate fire damage with paint peeling but not intumescing. The visual marker strobe lamp housings were intact but extensively burned such that it was impossible to see if the lamps had survived. The airfoil suffered minor structural damage, with assorted dents, etc. The SSFDR cavity was intact with the top surface of the recorder being blackened by fire. Figures 8 and 9 show the CPL RBA-46 as found at the B-720 crash site.

The extended plunger on the ARU-21 release unit indicated that the pyrotechnic deployment system operated. The radio beacon base (tray) suffered some heat and fire damage, and was charred and blackened by smoke.

The frangible switch in the nose survived and the switch in the belly was recovered and found to have actuated. It is assumed that this switch fired the ARU-21 squib. There were no other release switches installed in the normally open system in the aircraft.

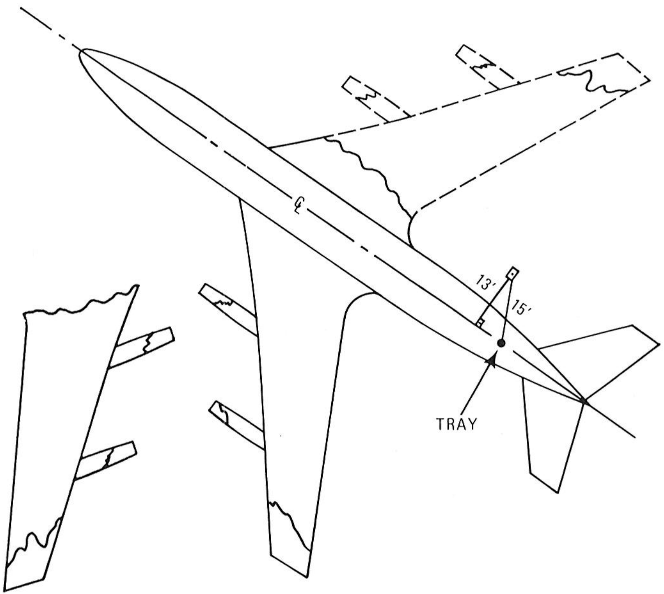

Figure 7
RBA-46 LOCATION RELATIVE TO B-720 AFTER CID

Figure 8
RBA-46 EXTERNAL SURFACE AFTER B-720 CID

Figure 9
RBA-46 INTERNAL SURFACE AFTER B-720 CID

POST B-720 CID ANALYSIS OF THE RBA-46 SSFDR/CPL

INITIAL INSPECTION

On December 10, 1984, the RBA-46 SN001 arrived at Leigh Instruments Ltd, Carleton Place, Ontario, Canada, for an engineering investigation of condition and performance. No modifications or work had been done to the airfoil since it was removed from the crash site at Edwards AFB, California.

Initial inspection showed charring on both sides of the airfoil. Structurally the airfoil was intact with various dents, etc. on its surface. The airfoil was soaked in fluids which were a combination of antimisting kerosene (AMK) jet fuel and fire fighting foam. Henceforth this fluid will be referred to as "crash fluid".

Upon removal of the BSO, the CPL did not transmit and the strobes did not flash. The airfoil was then subjected to a detailed analysis.

The MRU-57 Radio Beacon Base (tray) arrived at Leigh Instruments Ltd. on January 18, 1985. Initial inspection shows the tray to have suffered mild fire damage, slight charring, and paint peeling, and it was covered with smoke deposits.

All safety lock wire was intact and the plunger in the ARU-21 Release Unit was in the extended position. Removal and inspection of the squib showed it to have fired. None of the plastic or rubber components showed any sign of melting, indicating that the tray had not been subjected to prolonged fire. The rear mounting hooks showed no sign of damage. The break away connector showed minor signs of corrosion caused by the crash fluids.

The tray suffered minimal heat damage; as a consequence it is assumed that the cartridge was fired by the electrical input to the release circuitry and not by overheating.

PAYLOAD CAVITY ANALYSIS

The SSFDR was removed from the RBA-46 airfoil to provide access to the CPL payload cavity. Each assembly was then tested to determine its state. Figure 10 shows the payload cavity before disassembly.

The SSFDR case was wet with crash fluids. All the assemblies in the cavity had their encapsulating foam soaked with crash fluids. The fluids had seeped in around the SSFDR because there was no seal installed. Sediment due to corrosion was found on the SSFDR connector as well as on the surface of the foam and on the wiring harness. These consisted primarily of green copper deposits. Figures 11 and 12 show the SSFDR before disassembly.

The payload assemblies did not shift nor show any signs of sustaining physical damage due to heat (fire) or impact. The wiring harness was intact.

The crash fluids consisted of AMK jet fuel and fire fighting foam. The fire fighting foam is electrically conductive, very corrosive and has a very low surface tension. Low surface tension allows it to flow rapidly into cracks, etc. This fluid extensively damaged various components of the airfoil payload as shown in figure 13.

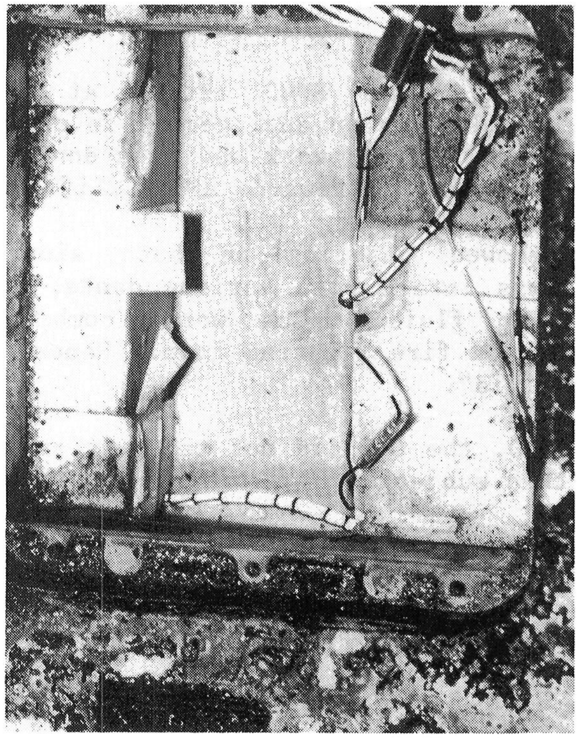

Figure 10
RBA-46 PAYLOAD CAVITY WITH SSFDR REMOVED

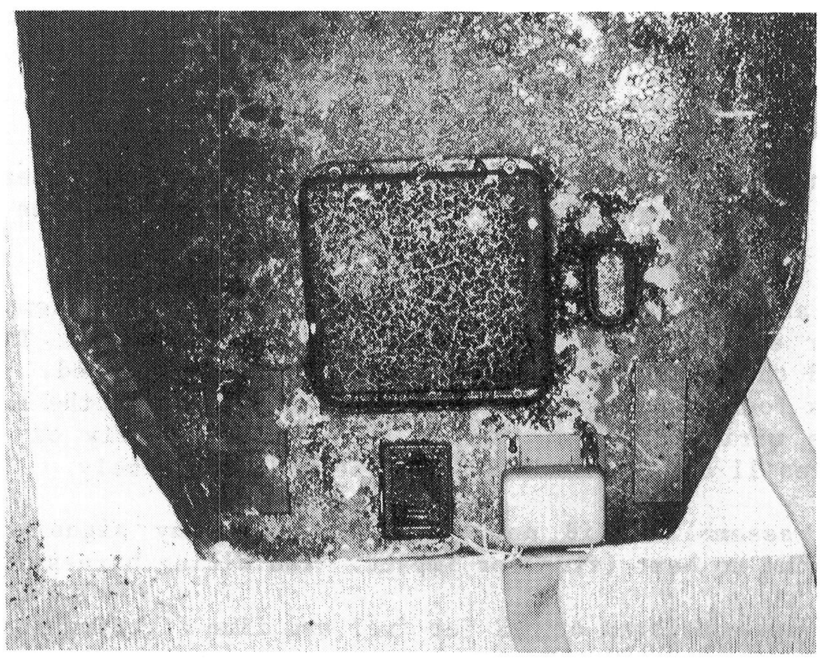

Figure 11
RBA-46 SSFDR EXTERNAL SURFACE PRIOR TO DISASSEMBLY

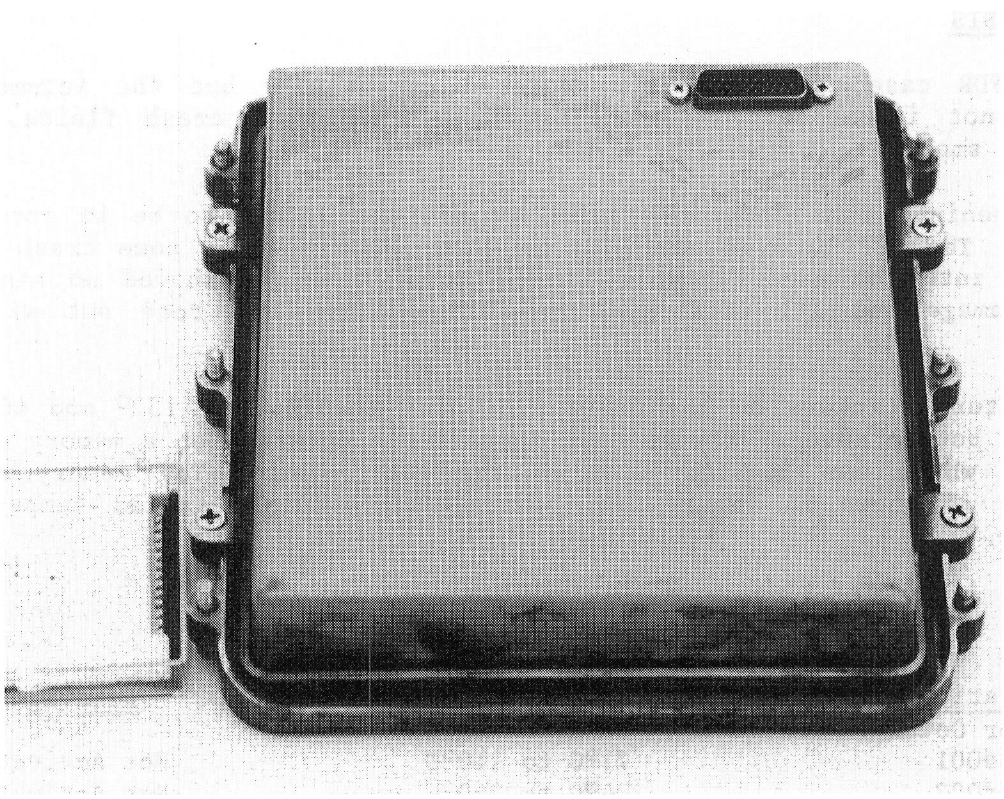

Figure 12
SSFDR INTERNAL SURFACE AFTER B-720 CID

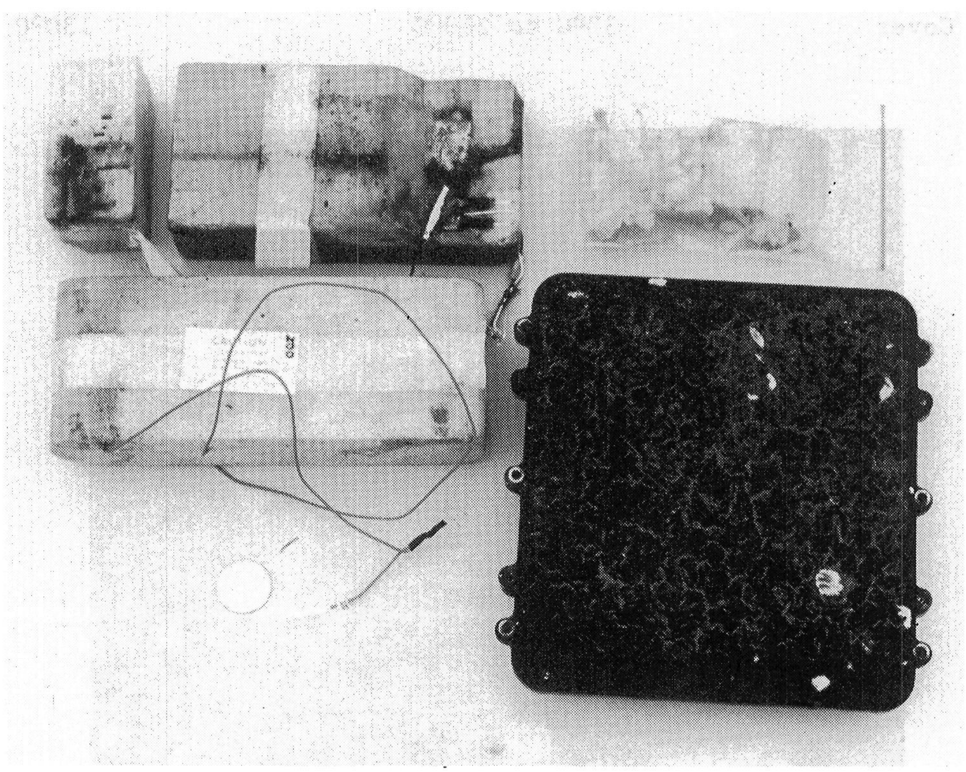

Figure 13
RBA-46 PAYLOAD COMPONENTS REMOVED FROM CAVITY

SSFDR ANALYSIS

The SSFDR case cover top was scorched extensively but the intumescent paint did not intumesce. The underside was wet with crash fluids, with evidence of smoke.

Upon opening, the interior of the recorder was found to be in excellent condition. The SSFDR cover seal was in good shape however some crash fluid had seeped into the memory modules. The memory modules showed no signs of physical damage and all data (checkerboard pattern) was read out with no errors.

Temperature stickers on the SSFDR indicated readings of 130° and 46° for the top and bottom cover. The highest temperature obtained on a memory module was 121°C, which was located next to the top cover. The memory module arrangement is shown in figure 14. Table 1 provides detailed temperature information.

Table 1
SSFDR Temperature Measurements

Location	Range	Readings
Interior Cover	37°C to 260°C	46°C
Module #001	71°C to 110°C	Not Activated
Module #002	204°C to 260°C	Not Activated
Module #003	37°C to 65°C	49°C
Module #004	160°C to 199°C	Not Activated
Module #005	116°C to 154°C	121°C
Exterior Cover	37°C to 260°C	130°C

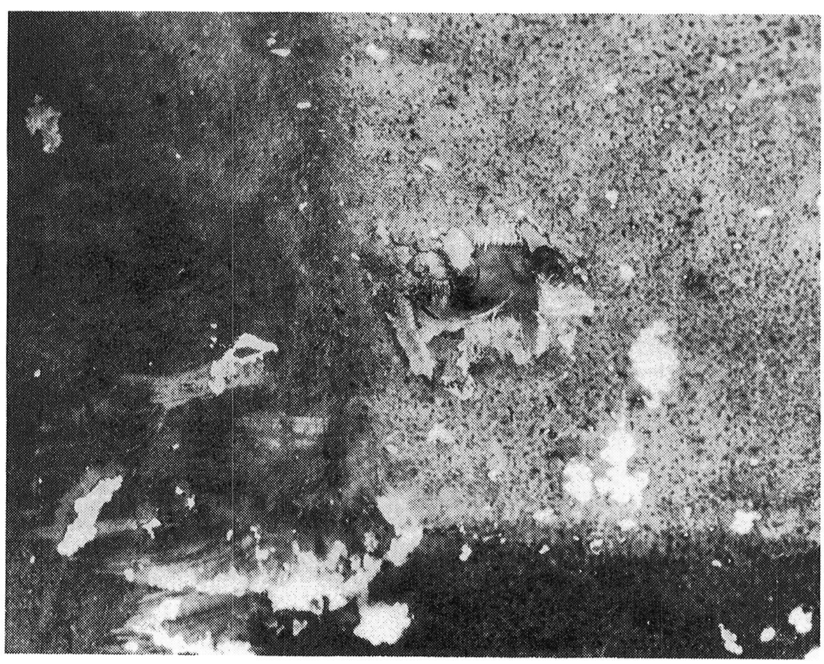

Figure 14
PUNCTURE IN RBA-46 AIRFOIL EXTERNAL SURFACE